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Invention Descriptions		540118
1. Invention Name:	Chinese:	A method to increase the surface wettability of low dielectric materials
	English:	
2. Inventor(s):	Names: (Chinese)	1. Cai Zhengyuan 2. Yang Mingsheng
	Names: (English)	1. 2.
	Nationality:	1. Republic of China 2. Republic of China
	Residence:	1. #14 Minzhu Road, Beigang, Yunlin County 2. 5 <sup>th</sup> Floor, #10, 165 Zhongxiao Road, Xizhu City
3. Applicant(s):	Name (Title): (Chinese)	1. United Microelectronics Corporation
	Name (Title): (English)	1.
	Nationality:	1. Republic of China
	Residence (Agency Location)	1. 300 Xinzhu Scientific Industrial Zone, #3 2 <sup>nd</sup> Lixing Road, Xinzhu City
	Name of Representative: (Chinese)	1. Xuan Mingzhi
	Name of Representative: (English)	

Invention Abstract in Chinese: (Invention Name: A method to increase the surface wettability of low dielectric materials)

The present invention relates to a method to increase the surface wettability of inorganic low dielectric materials. This method uses an inorganic dielectric material as the low dielectric barrier layer, and it forms on a semiconductor element using chemical vapor deposition method. Then, ultraviolet treatment method is used to treat the surface of the inorganic low dielectric material, so the property of the surface is changed from hydrophobic to hydrophilic. Therefore, the surface wettability of the inorganic low dielectric material can be improved; meanwhile it can increase the adhesion between the inorganic low dielectric material and the organic high polymers.

Invention Abstract in English: (Invention Name: )

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Applied national (regional) patent	Application Date	Case Number	Priority
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None.

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None.

## **5. Invention Descriptions**

### **5-1 Invention Field:**

This invention relates to a method of forming a low dielectric material on a semiconductor element, especially a method that can increase the surface wettability of inorganic dielectric materials.

### **5-2 Invention Background:**

On the applications of semiconductor manufacturing technology, integrated circuits containing sub-microns and sub-half-microns are currently being manufactured. And a deep sub-micron technology (for example, including less than 0.35mm sizes) is very necessary for the multilevel interconnection technology.

Therefore, inside the integrated circuit wafers, the role of the integrated circuits is to act as the delay time for the electronic signals moving between millions of gates and transistors in the deep sub-micron technology. The appearances of parasitic capacitance and resistance effect require that the protection for these interconnected structures must be controlled well. From this trend we can tell that the current emphases is on the application of low resistance metals (for example: copper), this type of metal connects to the insulation materials with low dielectric constants (low-k dielectric) using metal wires. A low dielectric material is a dielectric material; its dielectric constant is lower than those of the traditional dielectric materials, for example: fluorinated silicate glass (FSG) has a dielectric constant value of around 3.5. Compared to other metals (for example: aluminum), the conductivity of copper is very high, and its electromigration is lower.

Inside the semiconductor manufacturing technology, the preparation of interconnection layers uses the chemical mechanical polishing (CMP) method, especially when the features of layers and wire itself are represented by an aspect ratio (for example, wire is 0.25mm wide and 1.0mm tall).

During the manufacturing process of 0.25mm high efficiency integrated circuit, damascene technology must be used to prepare the interconnection structure. Due to the size issue of the semiconductor elements, deposition of traditional metal aluminum and etching gradually become more and more difficult. In the meantime, from the efficiency point of view, low resistance metals such as copper should be considered.

Besides copper with low resistance, the efficiency of integrated circuits is improved by the connection between copper conductor and low dielectric insulator (dielectric constant  $k$  is lower than 4). In many examples, some low dielectric materials are spin coated polymers. Also, in order to form a dual damascene structure, inorganic dielectric materials such as silicon nitride (SiN) or silicon carbide both use chemical vapor deposition (CVD) method to form, they can be used as the barrier layer, later spin coating is used to coat the low dielectric material onto the barrier layer. Therefore, because the material with low dielectric constant is an organic high polymer, the compatibility of the

above two materials, for example, the adhesion between two different materials is the key to impact the manufacturing process. Because the silicon carbide material itself contains Si-H bond and Si-CH<sub>3</sub> groups, these two groups both are hydrophobic. Generally before the formation of low dielectric material coating, silicon carbide (or silicon nitride) is coated with an adhesion promoter, the purpose of this promoter is to provide a dielectric material containing organic hydrophobic bonds (for example, Si-C) and inorganic hydrophilic bonds (for example, Si-O bond), so organic hydrophobic material can be evenly coated on the inorganic dielectric material. Therefore, whether this adhesion promoter can be evenly coated on the inorganic dielectric material will seriously affect whether the high polymer material with low dielectric constant can be evenly coated (that means good adhesion capability) on the surface, it further affects the integrity issue of the semiconductor element.

Due to the shortcomings we mentioned above, in order to increase the adhesion between the inorganic dielectric material and the organic high polymer, the surface properties of the inorganic dielectric material must be improved, such as: the wettability, so the surface of the inorganic dielectric material can be changed to a hydrophilic surface.

### 5-3 Invention Purpose and Overview:

The main purpose of this invention is to provide a processing method for a low dielectric material to be formed on a semiconductor substrate. This method can improve the wettability of the low dielectric material surface.

The other purpose of this invention is to improve the adhesion between the low dielectric material and the organic high polymer.

Based on the above purposes, the method of this invention is to use chemical vapor deposition procedure, first form an inorganic low dielectric material on the semiconductor element, the hydrophobic inorganic low dielectric material acts as a diffusion barrier layer or etching stop layer, and ultraviolet is used to treat the inorganic low dielectric material, so the surface property of the inorganic low dielectric material is changed to hydrophilic and the surface wettability is improved as well.

### 5-4 Detailed Invention Descriptions:

Some real-life examples below will explain this invention in more details. But, besides the detailed descriptions, this invention can be extensively used in other real-life examples, and the scope of this invention is not limited, it is described by the appended patent claims.

For low dielectric materials, especially spin coated polymer materials, organic high polymer, such as SiLK and low dielectric material, for example: the adhesion between silicon nitride (SiC), silicon carbide (SiN) is the key for whether this type of low dielectric material can be evenly coated. For the integrity of the semiconductor element, the adhesion property of material, for example the wettability is the main feature. On the

other hand, low dielectric material, for example, compared to traditional silicon nitride (SiN), silicon carbide (SiC), has lower dielectric constant, and it has better resistance capability for the diffusion of copper. To improve the adhesion between the organic polymer and the adjoining low dielectric material, ultraviolet is used on the surface of silicon carbide in order for the surface of silicon carbide to change from hydrophobic to hydrophilic, and the wettability of silicon carbide will increase as well. The ultraviolet treatment causes the silicon carbide surface to change from hydrophobic to hydrophilic, the reason is that ultraviolet can interrupt the bonding between Si-H and Si-CH<sub>3</sub> inside silicon carbide film to form Si-OH bond, therefore the hydrophilic property is improved.

Refer to Figure 1, the first low dielectric layer 12 containing a conductor zone 14 is formed on the substrate 10. The conductor zone 14 can be any metal material, and it forms an interconnected line in a semiconductor element. Generally speaking, for example: metal aluminum can be used as the metal material for the conductor zone 14 on the semiconductor element. Inside the recent real-life examples, metal copper replaced metal aluminum. Compared to metal aluminum, metal copper has higher resistance against electromigration and it has lower resistance value, therefore we can tell that metal copper can be a more appropriate material for the interconnected line. But, due to the diffusion effect of metal copper inside the dielectric material and the incompatibility between metal copper and silicon material, it is necessary for the metal copper to be separated from the adjoining material. Therefore, when the metal copper is used as the material for the interconnected line, a barrier layer or encapsulation layer must be used to separate the metal copper away from the adjoining material, and prevent any interactions between the metal copper and the adjoining material from happening.

Then, the inorganic dielectric material used as the first low dielectric barrier layer 16 is formed on the first low dielectric layer 12 and part of the conductor zone 14 by the chemical vapor deposition method. Inside the traditional technology, silicon nitride is used as the low dielectric barrier layer 16 in the interconnected structure. But, the dielectric constant of silicon carbide film is lower than that of silicon nitride and it has better resistance capability for metal copper, therefore silicon carbide is chosen as low dielectric barrier layer 16 in this real-life example.

Then, in a real-life example, ultraviolet is used to process the surface of the first low dielectric barrier layer 16, so the surface property of this low dielectric barrier layer is changed from hydrophobic to hydrophilic, it also improves the surface wettability of inorganic dielectric material and the adhesion between the inorganic dielectric material and the organic high polymer used as the low dielectric layer. In another real-life example, in order to improve the adhesion between the inorganic low dielectric material and the organic high polymer, an adhesion promoter is coated on the inorganic low dielectric material, the coating thickness is around 100 angstrom, and a baking method is used to bake the adhesion promoter at 100~200°C temperature in order to eliminate the solvent residue on the inorganic low dielectric material.

Later, refer to Figure 2 and Figure 3, a second low dielectric layer 18 is formed on the first low dielectric barrier layer 16 through coating method, then, a second low dielectric

barrier layer 20 is formed on the second low dielectric layer 18 through chemical vapor deposition (CVD) method, such as: plasma enhanced chemical vapor deposition (PECVD). The first photoresist layer utilizes the optical lithography to deposit on the second low dielectric barrier layer 20, it goes through exposure and development, and it etches the exposed area of the second low dielectric barrier layer 20 in order to form a via hole opening on the second low dielectric layer 18 defined by opening 24. Then, refer to Figure 3, a third low dielectric layer 26 is formed on the second low dielectric barrier layer 20 through the same spin coating method, later a hard mask layer 28 is deposited on the third low dielectric layer 26.

Then, refer to Figure 4, a second photoresist layer deposits on the hard mask layer 28, and it goes through exposure and development through the known optical lithography to form a gutter opening defined by the opening 30. Therefore, the optical lithography removes the partially exposed area of the hard mask layer through etching to form the opening 30.

Refer to Figure 5, unisotropic etching procedure is used to form a via hole 32 and a gutter opening, the unisotropic etching is also used to etch the exposed third low dielectric layer 26 and the second low dielectric layer 18 to form a dual damascene structure. This unisotropic etching method will etch the exposed third low dielectric layer 26 and the second low dielectric layer 18 in order, but the low dielectric barrier layer 20 and 16 will not be removed by etching.

Refer to Figure 6, metal copper deposits and fills the via hole opening 32 and the gutter 34. Generally speaking, when the metal material deposits, the metal residue will also form on the structure. Therefore, the metal copper residue can be removed through etching procedure or polishing technology. Inside the best real-life example, the metal copper on the gutter opening 34 is removed through chemical mechanical polishing (CMP) to form a metal plug 36. Later, the third low dielectric barrier layer 40 deposits and covers the hard mask layer 28 and part of the metal plug 36. If repeating the above procedure, extra metal layers can be formed on the structure in Figure 6 to create a multiple-layered interconnected line structure.

While the above is some good examples of this invention, they are not used to limit the applicable scope for this invention; variations and modifications thereof without departing from the spirit and scope of the invention are all included in the scope of the invention described by the appended patent claim.

## **Simple Descriptions of the Figures**

Figure 1 is the diagram of the structure in the first dielectric layer containing a conductor zone and the first barrier layer on the first dielectric layer;

Figure 2 is the cross section diagram of the second dielectric layer, the second barrier layer formed in order on the structure shown in Figure 1 and a opening located on the second barrier layer inside the second low dielectric layer;

Figure 3 represents the formation of the third dielectric layer and hard mask layer in order on the structure shown in Figure 2;

Figure 4 represents an opening located inside the hard mask layer and the third dielectric layer formed on the structure shown in Figure 3;

Figure 5 shows a via hole opening and a gutter opening in the structure shown in Figure 4; and

Figure 6 shows the cross section diagram of a dual damascene structure formed on a substrate.

Symbols used for the main parts:

- 10 substrate
- 12 first low dielectric layer
- 14 conductor zone
- 16 first low dielectric barrier layer
- 18 second low dielectric layer
- 20 second low dielectric barrier layer
- 24 opening
- 26 third low dielectric layer
- 28 hard mask layer
- 30 opening
- 32 via hole opening
- 34 gutter
- 36 metal plug
- 40 third low dielectric barrier layer



## **VI. Patent Claims**

1. A formation method for a semiconductor element, wherein this method includes:

A dielectric layer forms on a semiconductor substrate;

A barrier layer forms on this dielectric layer; and

Ultraviolet is used to treat the barrier layer, so the surface property of this barrier layer changes from hydrophobic to hydrophilic.

2. The method of Claim 1, wherein the above dielectric layer includes organic high polymers containing SiLK.

3. The method of Claim 1, wherein the above barrier layer includes inorganic dielectric materials containing silicon nitride and silicon carbide.

4. The method of Claim 3, wherein the formation of the above barrier layer includes a chemical vapor deposition method.

5. The method of Claim 1, wherein it further includes an adhesion promoter to cover the barrier layer.

6. A method to form a dual damascene structure, wherein it includes:

It provide a semiconductor structure with a substrate, the first dielectric layer containing a conductor zone forms on this substrate, the first barrier layer forms on the above first dielectric layer and the conductor zone, a second dielectric layer forms on the above first barrier layer, a second barrier layer forms on the second dielectric layer, a third dielectric layer forms on the above second barrier layer;

A gutter is formed with the conductor zone on the first dielectric layer inside the third dielectric layer, the second barrier layer, the second dielectric layer and the first barrier layer; and

Ultraviolet is used to treat the surfaces of the first barrier layer and the second barrier layer so that their properties can be changed from hydrophobic to hydrophilic.

7. The method of Claim 6, wherein the material of the above conductor zone contains metal copper.

8. The method of Claim 7, wherein the above metal copper is polished by a chemical mechanical polishing procedure.

9. The method of Claim 6, wherein the above first dielectric layer, the second dielectric layer and the third dielectric layer all contain organic high polymers with SiLK.

10. The method of Claim 6, wherein it further includes a barrier layer of inorganic dielectric material containing silicon nitride, the barrier layer is deposited on the above first dielectric layer, the second dielectric layer and the third dielectric layer by chemical vapor deposition process.

11. The method of Claim 10, wherein the chemical bonds of the above silicon nitride include silicon-hydrogen (Si-H) bonds.

12. The method of Claim 10, wherein the chemical bonds of the above silicon nitride include silicon-hydrocarbon (Si-CH) bonds.

13. The method of Claim 6, wherein it further includes an adhesion promoter that covers the above first barrier layer and the second barrier layer.

14. The method of Claim 13, wherein it further includes a baking procedure for the above adhesion promoter.

15. A method to form a damascene structure, wherein the method includes:

It provide a semiconductor structure with a substrate, the first organic high polymer layer containing a conductor zone forms on this substrate, the first inorganic dielectric layer forms on the above first organic high polymer layer and the conductor zone, a second organic high polymer layer forms on this first inorganic dielectric layer, a second inorganic dielectric layer forms on the second organic high polymer layer, a third organic high polymer layer forms on the above second inorganic dielectric layer;

A gutter is formed with the conductor zone on the first organic high polymer layer inside the third organic high polymer layer, the second inorganic dielectric layer, the second organic high polymer layer and the first inorganic dielectric layer; and

Ultraviolet is used to treat the surfaces of the first inorganic dielectric layer and the second inorganic dielectric layer so that their properties can be changed from hydrophobic to hydrophilic.

16. The method of Claim 15, wherein the material for the above conductor zone contains metal copper.

17. The method of Claim 16, wherein the above metal copper is polished by a chemical mechanical polishing procedure.

18. The method of Claim 15, wherein the above first organic high polymer layer, the second organic high polymer layer and the third organic high polymer layer all contain organic high polymers with SiLK.

19. The method of Claim 15, wherein it further includes a inorganic dielectric layer that is spin coated on the above first organic high polymer layer and the second organic high polymer layer.

20. The method of Claim 15, wherein the above first inorganic dielectric layer and the second dielectric layer both include inorganic dielectric materials containing silicon carbide and silicon nitride.

21. The method of Claim 20, wherein the above silicon nitride includes silicon-hydrogen (Si-H) chemical bonds.

22. The method of Claim 21, wherein the above silicon nitride includes silicon-hydrocarbon (Si-CH) chemical bonds.

23. The method of Claim 15, wherein it further includes an adhesion promoter that covers the above first inorganic dielectric layer and the second inorganic dielectric layer.

24. The method of Claim 23, wherein it further includes a baking procedure for the above adhesion promoter.